WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Dynamic Simulation Of Water Distribution Systems With Instantaneous Demands

Focus Categories: Wqn, Ws, Mod

Keywords: Water Demand, Water Distribution Systems, Water Use Monitoring, Dynamic Simulation, Unsteady Flow.

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Principal Investigators: Walter F. Silva, Department of General Engineering, University of Puerto Rico at Mayaguez Noel Artiles, Department of Industrial Engineering, University of Puerto Rico at Mayaguez.

Congressional District: N/A

Statement Of The Problem

Accurate predictions of water quantities are needed for efficient city planning in regions where land is limited for an ever increasing population, the competition for water is intense, and the water availability problems are complex. Puerto Rico is still suffering a water crisis caused by inappropriate management of the water infrastructure, which has revealed as serious water allocation and distribution problems. This problem is aggravated by frequent shut downs of water treatment facilities due to poor quality of the effluents. Moreover; water quality in residential distribution networks deteriorates between the treatment plant and the consumer's tap. This fact has deep consequences for the drinking-water utilities because the new regulations proposed by the Safe Drinking Water Act (SDWA) require the fulfillment of drinking-water standards at the household entrance (Clark et al., 1993). It is very doubtful that, under present conditions, Puerto Rico could fulfil these standards.

Therefore, efficient urban planning and development; as well as, the challenge posed by the SDWA motivate the creation of a new generation of promising methodologies which combine a detailed representation of water demand scenarios with time-dependent hydraulic models for reliable predictions of water quantity and quality in distribution systems.

Benefits

The benefits and products of this project are a new methodology to simulate the operation of water distribution systems under a fine scale resolution of spatial and temporal water demands. The products include: (1) a stochastic water demand model that can be used alone for estimating water consumption volumes in residential areas and, (2) a fully dynamic unsteady flow algorithm coupled to the water demand model for flow simulations.

Possible applications of this model by the water community include: studies for planning, management and operation scenarios of the water system; and, analysis of emergency conditions such as pump shut-downs, failures of control valves or any other severe pressure surge. The model will also be useful to increase the understanding of unsteady flow in pipe networks and to improve water quality simulations.

Nature of the project

Commonly used computer programs for pipe networks use spatial and temporal average demands. Spatial average is usually obtained by assigning the consumption along a pipeline to the nodes of the skeleton of the supply network. Steady-state models do not consider temporal variations. Extended-period simulation modeling is an attempt to include temporal variations by considering a sequence of successive steady-state periods where control mechanisms and demand conditions are allowed to vary from one steady-state to another. Both of these modeling techniques have been used for water quality and quantity analysis with limited success in prediction of constituents concentrations in the system (Grayman et al. 1988, Clark et al., 1993). More realistic modeling of water quality calls for dynamic hydraulic models, because the concentration of constituents changes continuously over time and space according to the random variations in water consumption caused by the users in a service area.

A further refinement in pipe network modeling techniques is the use of fully dynamic unsteady flow models. If inertia effects are important or when the flow becomes more unsteady, results of extended period simulations (including flow magnitudes, flow directions and chlorine concentrations) are significantly different from results obtained with a fully dynamic model.

The predictions of water quantity and quality in pipe network are considerably affected by the assumed spatial and temporal distribution of consumptive demand. Simulations could be improved if the unsteady flow model for the water system is coupled to an instantaneous water demand model capable of representing the random variations in the water consumption patterns at the residences of a neighborhood. This project will develop a methodology for simulating the instantaneous water demand and integrating it with a fully dynamic hydraulic model to produce a careful and detailed representation of the operation of a water distribution system.

Scope

This project will develop an analytical methodology to model instantaneous residential water demands in a neighborhood. The methodology has two components: a water demand model and a hydraulic model.

The instantaneous demand will be modeled by using stochastic simulation. Residential flows and pressures at the entrance of representative houses in a neighborhood in Puerto Rico will be collected to determine the parameters of the probability distributions and to select the ones that best represent the consumer's behavior.

The stochastic model will be used to generate several sequences of closure and opening of faucets in a laboratory setup to study the variability in the volume of consumed water for the same set of model parameters. The operation of the laboratory system will be simulated by coupling the hydraulic and the stochastic models. The result will be a very fine representation of the behavior of the pipe system. Measured and computed flow demands will be compared to evaluate the degree of applicability of the new modeling technique.

Objectives

The objectives of this research are:

1. To develop an analytical stochastic methodology to model instantaneous residential water demands in a neighborhood.

2. To provide a micro-scale simulation algorithm that couples an unsteady flow model and the instantaneous demand model. The new algorithm could have applications in planning, management and optimization of potable water uses and allocation. The algorithm could be enhanced adding a water quality model to perform accurate simulations of contaminant propagation or chlorine concentrations at the entrance of consumer houses.